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G. Yuce, D. Ugurluoglu. Technical NoteEarthquake dates and water level changes in wells in the Eskisehir region, Turkey. Hydrology and Earth System Sciences Discussions, 2003, 7 (5), pp.777-781. hal-00304930

HAL Id: hal-00304930

<https://hal.science/hal-00304930>

Submitted on 1 Jan 2003

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Technical Note:

Earthquake dates and water level changes in wells in the Eskisehir region, Turkey

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Abstract

Although satisfactory results have yet to be obtained in earthquake prediction, one of the most common indicators of an anomalous precursor is a change in groundwater level in existing wells. Further wells should thus be drilled in unconfined aquifers since these are more susceptible to seismic waves. The Eskisehir region lies in the transition zone between the Aegean extensional domain and the compressible northern Anatolian block. Limnigraphs, installed in 19 exploration wells in the Eskisehir region, recorded pre-seismic, co-seismic and post-seismic level changes during the earthquakes of 17 August Izmit ($M_w = 7.4$) and 12 November Duzce ($M_w = 7.2$) 1999 that occurred along the North Anatolian Fault Zone. The Izmit and Duzce earthquakes affected groundwater levels, especially in confined aquifers. The aquifer characteristics before and after the earthquakes were unchanged so the aquifer is elastic in its behaviour. Further detailed geo-mechanical investigation of the confined aquifer in the Eskisehir region may improve understanding of earthquake prediction.

Keywords: earthquake prediction, Eskisehir, hydrological warning, monitoring groundwater levels

Groundwater level changes during and after the 1999 Earthquakes in Turkey

To observe the effects of water consumption, recharge and other influences on the hydrology of the Eskisehir region, electronic limnigraphs recording to 1 mm were installed in 19 observation wells. Figure 1 (Saroglu, 1992) shows the locations of these wells on a simplified geological and tectonic map on which are given the epicentres of earthquakes from March 5, 1998 to October 4, 2003. The water level fluctuations in the wells have been plotted (Figs. 2 and 3) to investigate the influences of the earthquakes (manual adjustments are indicated on the graphs).

Well No. 3: an increase of 5 cm was observed during the August 1999 earthquake. The difference between the maximum and minimum levels reached 10 cm and there was no effect of the November 1999 earthquake. *Well No. 4:* groundwater level began to decrease before the 1999 earthquakes and an 80 cm drop occurred on August 17, 1999. The difference between the maximum and minimum level

was 96 cm. The water level recovered within 3 weeks. No change in water level was associated with the November 1999 earthquake and the difference between the maximum and minimum levels was 35 cm. A 7 cm drop in water level on November 13 and 13 cm on November 14, was balanced by a 22 cm rise on November 16, 1999 (Fig. 2). *Well No. 5:* a rapid decrease in water level started from June 1999 and a 7 cm drop occurred on August 17, 1999. The difference between the maximum and minimum levels was 11 cm. No effect of the November 1999 earthquake was observed (Fig. 2). *Well No. 8:* an increase totalling of 50 cm in water level started from May 13, 1999 and there was a sudden uplift of 99 cm during the August 1999 earthquake. An increase of 2 cm on November 12, 1999 was followed by 24 cm increase on November 14, 1999 (Fig. 2). *Well No. 10:* although water level dropped 20 cm in August 1999, there is no record for the November 1999 earthquake. *Well No. 11:* groundwater level decreased 20 cm with the August 1999 earthquake. The difference between the maximum and minimum level reached 30 cm on November 13, 1999 with a 3 cm increase



Fig. 1. The location of the recording wells on a simplified geological and fracture map (modified by MTA, 1997).

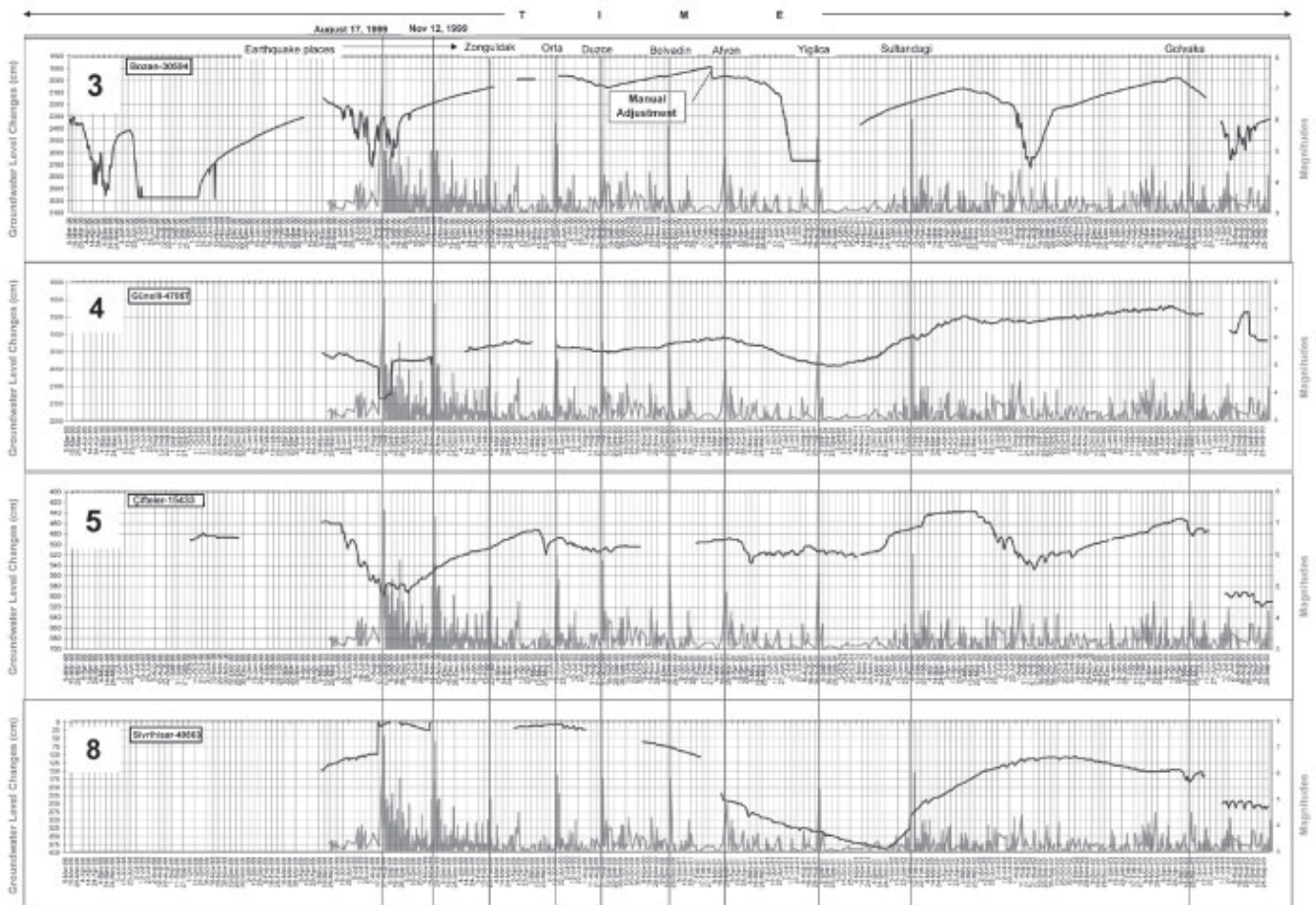


Fig. 2. Graphs for time versus groundwater in recording wells and the magnitude of earthquakes between 5 March 1998 and 4 October 2003.

in water level. The difference between the maximum and minimum level was around 19 cm. *Well No. 12*: there are no groundwater level records for August 17, 1999 and no effect of the November 12, 1999 earthquakes. The difference between the maximum and minimum level was 12 cm. The increase in water level recorded starting from November 5, 1999 was 5 cm (Fig. 3). *Well No. 13*: a 12 cm drop in water level occurred at the time of the August 12, 1999 earthquake and the decrease in groundwater level continued until August 17, 1999. *Well No. 17*: records for August 1999 do not exist. The difference between the maximum and minimum level was 33 cm. Note the drop of 50 cm in water level on November 13, 1999 (Fig. 3).

Wells No. 1, 6, 7, 9, 14, 18 and 19: effects of the 1999 earthquakes and others are neither observed nor recorded.

The rapid pre-seismic water level decrease in groundwater levels in Wells No: 5, 10 and 12, observed in February 2000 may be related to the February 14, 2000 Orta (Cankiri) earthquake (Magnitude- $M_w = 5.9$ and Epicentre Depth-

ED = 9 km) and post seismic shocks ($M_w = 5-5.2$ ED = 20-22 km) (Fig.2 and Fig. 3). The Sultandagi earthquake ($M_w = 6.0$) on 3rd February 2002, affected the water level in Well No: 8 with as 34 cm rise (Fig. 2). Also a 3 m post-seismic rise was observed in the Sultandagi well (Fig. 1), which was very close to the rupture zone. Field observations noted no remarkable changes in chemical anomalies apart from normal seasonal effects (*personal communication with Dr Levent Tezcan*). Except for Well No: 8, water levels returned to their initial positions 3–4 days later. Similar changes had been seen after the Golyaka earthquake ($M_w = 4.5$, May 21, 2003) in Wells No: 8 and 5 (Fig. 2). Those changes can be interpreted as elastic bounds due to earthquakes.

Discussion

The groundwater level changes which are clearly observed in Well No: 8 in August and November 1999 earthquakes

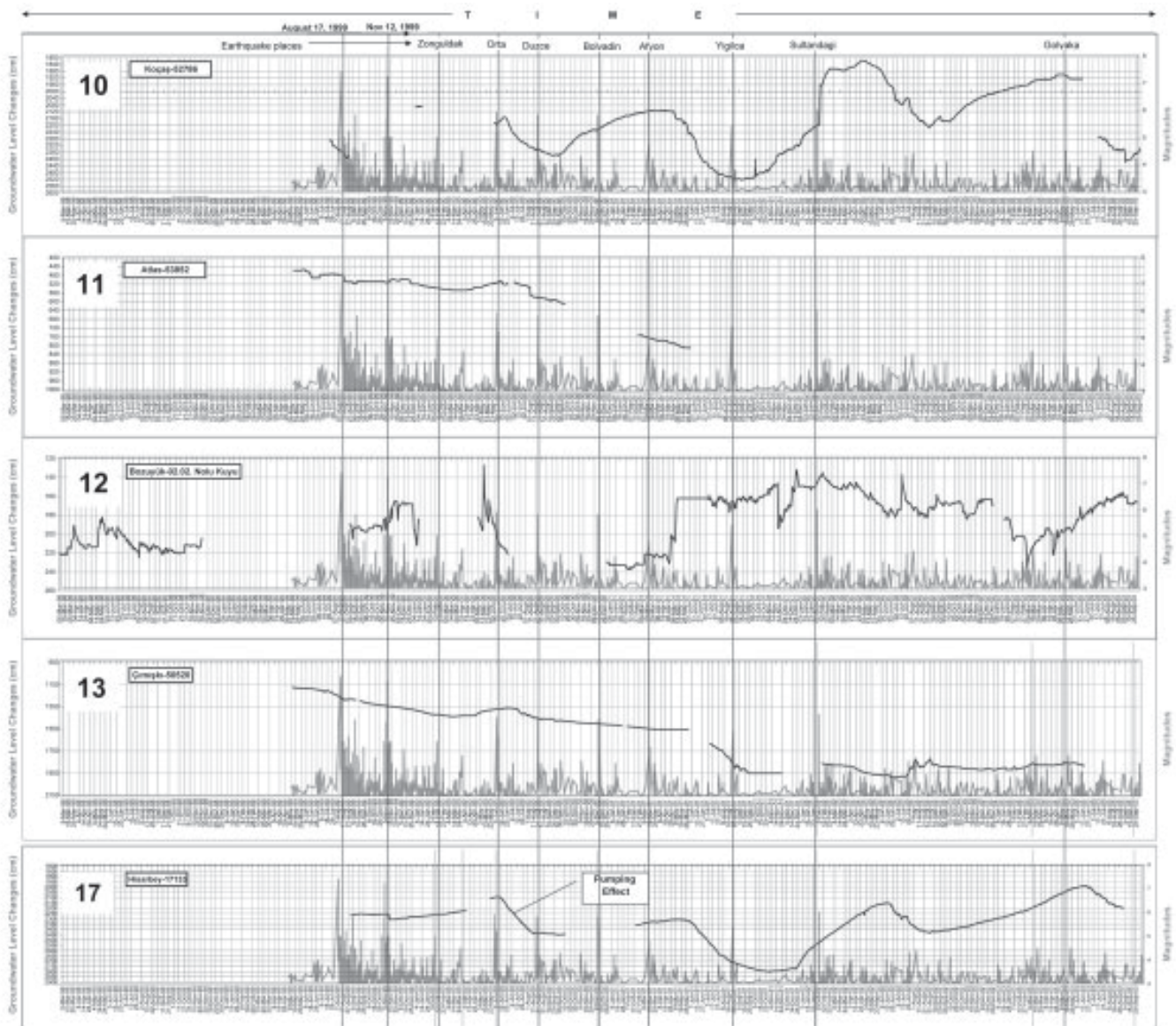


Fig. 3. Graphs for time versus groundwater in recording wells and magnitude of earthquakes between 5 March 1998 and 4 October 2003.

have been examined with the barometric pressure and precipitation measurements before and after the earthquakes. There was no rainfall just before these 1999 earthquakes and no significant variations in the barometric pressure readings, so the sudden increase in water level of Well No: 8 seems to be related to the earthquake (Galloway *et al.*, 1994). The reactions typically observed in confined aquifers during earthquakes (Roeloffs, 1988) did not occur in Well No: 9, 7.5 km distant from Well No: 8.

The compression of the aquifer during the earthquake and the consequent increase in pressure in the porous media, leads to the conclusion that the liquid has moved to where the pressure is released i.e. upwards (Sibson *et al.*, 1975).

The exponential return of the groundwater level to its initial position can be attributed to the different compressibility (\pm) of the aquiclude/aquifer conditions ($\alpha_{\text{clay}} > \alpha_{\text{sand}} > \alpha_{\text{gravel}}$, Freeze and Cherry, 1975). Pumping a well in a confined aquifer will release water from elastic storage determined by the elastic specific storage (Delleur, 1999).

Conclusion

The importance of hydrogeological data is a reality accepted by earthquake prediction scientists (King *et al.*, 1999; Koizumi *et al.*, 1996; Arabelos *et al.*, 2001). However, in addition to hydrological data, seismic net, deformation net

(tiltmeter, extensiometer, dilatometer, and GPS measurements), field excursions, paleo-seismologic and micro zoning activities, electromagnetic net, acoustic wave emissions and geophysical studies are all required. Sudden changes in groundwater levels are common in aquifers where the hydraulic diffusion ($D=T/S$) is distributed heterogeneously (Grecksch, 1999; Kümpel, 1997; Janssen, 1998).

As the aqueous and non-aqueous conditions of the environment and hardness or softness of formations influence the enlargement of amplitudes, the different reactions of the aquifer to waves from different depths may be explained by knowledge of many of the parameters mentioned above. Additionally, affected as they are by the strain-release forces in the earth's crust, the changes in groundwater levels before the rupture should be traced and discussed.

Acknowledgements

The authors wish to express their sincere appreciations to DSI (State Hydraulic Works) III Region Deputy Director, Nazmi Mumcu, Erkut Catalyurekli, Manager of Geotechnical Services and Groundwater Division, Sakir Ozcelik chief engineer, Erdal Celikmen and all the members of the section. The comments of Erol Onhon and Ugur Kuran were helpful in improving this manuscript.

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